ARCADIS
Infrastructure, buildings, environment, communications

ARCADIS G&M, Inc.
1400 N. Harbor Blvd. Suite 700
Fullerton, California 92835-4127
Tel: 714.278.0992
Fax: 714.278.0051

Subject:
Summary of Pre-Injection Test, Lot 8,
Building 136 Memo

Date:
March 9, 2005

From:
Trent Henderson, P.E., DEE

Drafted by:
Vincent Salazar
Eric Lothman, P.E.

Department:
Environmental

ARCADIS Project No.:
CA000594.0007.00007

To:
Stephanie Sibbett-Brutocao, Boeing
Robert Scott, Boeing
John Scott, Boeing
Brian Mossman, Boeing
Mario Stavale, Boeing Realty Corporation

Copies:
Alistaire Callender, ARCADIS
Fred Payne, ARCADIS
Barry Molnaa, ARCADIS

ARCADIS has prepared this report to summarize and analyze the data collected during the Pre-Injection Test conducted at the former Boeing C-6 facility (Site), Lot 8, Parcel C, Building 136 area in Los Angeles, California. The Pre-Injection Test was conducted on November 8 and 9, 2004 according to the scope of work described in *Proposal to Perform a Pre-Injection Test, Lot 8, Building 136, Former C-6 Facility, Los Angeles, California* dated November 1, 2004.

The purpose of the Pre-Injection Test was to:

1. Verify that the bio-amendment wells can accept the full design volume of a 10 percent carbohydrate amendment solution;
2. Develop injection procedures to maximize the introduction of solution into water-bearing units from amendment points;
3. Obtain process parameters (e.g., injection flow rates, injection pressures, etc.) that will be used in subsequent carbohydrate injection events; and
4. Develop contingency plans to address unforeseen amendment system pressure/flow issues.

The Pre-Injection Test was divided into two sections:

1. Testing of wells with injection of an un-buffered carbohydrate solution; and
2. Testing of wells with a buffered carbohydrate solution.

BACKGROUND

The overlying issues that prompted the injection test at Lot 8, are the difficulties encountered in the injection program at the Boeing C-6, Building 2 site. Since the full-scale design of the injection program for Lot 8 has not been finalized, a pilot injection test was deemed beneficial to evaluate the integrity of the bio-amendment injection wells, test alternate buffers, and collect field data for designing the injection system and process parameters to be used during future injection events. Currently, the Lot 8 site is undeveloped and modifications to the final injection design can be implemented without significant impact to the project.

RESULTS OF PRE-INJECTION TEST

This section discusses the field activities and results from the November 8 and 9, 2004 injection tests, including:

- Pressure at well heads
- Injection test data
- Water flush data
- Groundwater levels in monitoring wells

Pressure at well heads

Pressure build-up from the production of gas through physical or chemical reaction of the injection solution has been an issue during injection events at the Boeing C6, Building 2 site. Wellhead pressure data was recorded during the Lot 8 injection event to test the generation of gas due to buffering solutions, reaction of the carbohydrate solution with formation water, or fermentation. Pressure data was recorded prior to injection, before and after water flushing, and one week after the test. The wellhead pressure data is presented below:

Wellhead Pressure Data:

Well	Date	Buffer	Before Injection	After Injection	Comments
AW0095C	11/08/04	None	0.0 psi	-22 in Hg	Amendment addition; Flushed (11/09)
	11/10/04		2.0 psi		No injection conducted this day
	11/15/04		8.0 psi		No injection conducted this day
AW0098B	11/08/04	None	0.0 psi	-28 in Hg	Amendment addition; Flushed (11/09)
	11/10/04		1.0 psi		No injection conducted this day
	11/15/04		1.0 psi		No injection conducted this day
AW0033C	11/09/04	Sodium Phosphate	0.0 psi	-26 in Hg	Amendment addition
	11/10/04		13 psi	-20 in Hg	Flushed with potable water.
	11/15/04		11.5 psi		No injection conducted this day
AW0077B	11/09/04	Sodium Phosphate	0.0 psi	NM	Amendment addition
	11/10/04		13 psi	-14 in Hg	Flushed with potable water.
	11/15/04		3.0 psi		No injection conducted this day

Notes: psi = pounds per square inch; in Hg = inches of mercury; and NM = not measured

The wellhead pressure data collected during this test indicates a build-up of pressure in all amendment points. Buffering the solution did not have a significant effect on the generation of pressure. The pressure data collected on November 15, 2004, revealed increased pressure in the amendment points screened within the C-Sand formation. Because the un-buffered amendment solution reacted similarly to the buffered amendment solution, it can be concluded that the buffer does not significantly affect gas generation and pressure. Pressure build-up can be attributed to gas generation from fermentation of the carbohydrate solution, and the inability of the formation to dissipate the gas pressure.

Injection Data

Injection volumes, in the Boeing C6, Building 2 Bio-Amendment Injection Plan are based on a target concentration of total organic carbon (TOC) in the formation, the half-life of the donor substrate (amendment), and on the effective injection radius. The design volume for the Lot 8 wells, based on 48 gallons of injection solution per foot of well screen, was 1,200 gallons per amendment point.

Beginning on November 8, 2004, an injection test was conducted on the selected amendment points at Lot 8, Building 136 to collect field data of injection parameters for the full design volume of 1,200 gallons. The

amendment points selected for the test injection were those that accepted water at the slowest flow rates during the well seal testing performed by Haley & Aldrich. This injection test was conducted using a 5,000-gallon food-grade tanker truck containing 2,400 gallons of an un-buffered molasses solution on the first day and 2,400 gallons of a sodium phosphate buffered molasses solution on the second day. In order to minimize costs and expedite data collection and analysis, each injection was limited to one day. The tanker truck was connected directly to a 12-arm injection manifold that was mounted in the back of a pick-up truck to deliver the solution to two amendment points. Each arm of the injection manifold consisted of a flow control valve, flow totalizer, check valve, and pressure gauge. This equipment and instrumentation was used to monitor the injection flow rate and pressure at each amendment point during the injection test.

The design injection volume for each well was 1,200 gallons of amendment solution. Four test wells were selected, two test wells screened in the B-Sand (AW0077B and AW0098B) and two test wells screened in the C-Sand (AW0074C and AW0095C). Each type of solution—un-buffered and buffered—was injected into the test wells screened within the B- and C-Sand. Solution was delivered to two amendment points per truck load using the hydraulic pump on the tanker truck. To adhere to the proposed injection schedule and avoid disposal costs for unused solution, amendment solution was diverted to the fastest flowing amendment point if it was determined that the volume could not be completed before the end of the day. A summary of injection data is presented below:

Injection Data Summary

Well	Date	Volume (gallons)	Flow Rate (gpm)	Injection Pressure (psi)	Comments
AW0095C	11/08/04	747	0.9 – 2.3	17 - 25	Without buffer
AW0098B	11/08/04	1,564	2.5 – 5.0	16 - 25	Without buffer
AW0033C	11/9/04	1,328	16.0 – 16.5	12	Sodium phosphate buffer
AW0077B	11/9/04	1,068	0.2 – 4.8	20 - 27	Sodium phosphate buffer

Note: gpm = gallons per minute; psi = pounds per square inch.

It was observed during injection into AW0077B that the flow rate quickly diminished from an initial injection flow rate of 4.8 gallons per minute to less than one gallon per minute after injection of approximately 900 gallons. This observation was not typical in the other amendment points, and may be attributed to gas accumulation in the well or a limitation in the hydraulic capacity of the aquifer in this area. Another field observation was the formation of a "brown coagulate" in the injection solution. Based on discussions with the molasses supplier, solution mixing and delivery facility personnel, and Senior ARCADIS technical personnel, it was concluded that the material was an accumulation of dead yeast cells in the molasses solution. Although the solution was filtered prior to delivery to the site, fermentation occurs during transport to the site and in the tanker truck during the injection and may have led to a proliferation of yeast in the tanker during transport. Complete injection data and field observations for the pre-injection test are provided in Table 1.

Water Flush

In order to prevent bio-fouling, the amendment points were flushed with potable water after the last day of injection. The results of the water flush are presented below:

Water Flush Data:

Well	Date	Volume (gallons)	Comments
AW0095C	11/09/04	50.2	Normal potable water flush.
AW0098B	11/09/04	58.3	Normal potable water flush.
AW0033C	11/10/04	50.4	Normal potable water flush.
AW0077B	11/10/04	50.1	Normal potable water flush.

Groundwater Level Measurements

Groundwater levels were recorded using data loggers that were placed in selected amendment points and monitoring wells by a field representative from Haley & Aldrich. Haley & Aldrich provided transducer data from the six monitoring and amendment wells. The groundwater elevation data collected during the injection period was plotted on graphs to evaluate the influence of the amendment injection on the groundwater table. Figures 1 through 9 contain the groundwater elevation data versus time. The following is a summary of the data and observations made during the pre-injection tests:

November 8, 2004 Amendment Delivery:

- AW0033C – Minimal influence was observed (Figure 1). This influence can be attributed to the long distance (265 and 275 feet) between the amendment points and the observation well.
- AW0050C – An unusually large decrease (1 foot) in elevation occurred at approximately 11:00 a.m. Other than this point, fluctuations of less than 1 inch were observed (Figure 2). The amendment points were 200 and 240 feet away. This data suggests that the amendment injection has minimal influence on groundwater elevation at this distance.
- AW0082C – A decrease (approximately 2.5 inches) in elevation occurred at approximately 11:00 a.m., similar to AW0050C (Figure 3). Amendment points AW0095C and AW0098B are 170 feet to the southwest, and 100 feet to the west southwest of AW0082C, respectively.
- TMW08 – An increase in groundwater elevation of approximately 1 inch was observed (Figure 4). Amendment points AW0095C and AW0098B are 90 feet to the northwest, and 60 feet to the north northeast of TMW08, respectively. A slight decrease was observed while well AW0095C was

taken offline for repair. A gradually decrease in groundwater elevation was observed after testing was completed.

November 9, 2004 Amendment Delivery:

- AW0050C – An approximate 0.5 foot increase in groundwater elevation was observed (Figure 5). The increase was observed concurrent to amendment injection into amendment point AW0033C (90 feet to the northwest). Both points are screened in the C-Sands.
- AW0082C – A sharp decrease of approximately 3.5 inches in elevation was observed at approximately 10:00 a.m. (Figure 6). The amendment points are 170 and 210 feet away. This data suggests that the amendment injection has minimal influence on groundwater elevation at these distances.
- AW0095C – An observed increase of over 8 inches in groundwater elevation (Figure 7) correlates with the amendment delivery into amendment point AW0077B 90 feet away to the north northwest, although the two points are screened in two different sand zones (B- and C-Sands). This observation suggests that amendment point AW0033C, 270 feet to the north, has minimal impact on this monitoring well due to the distance between the wells.
- AW0098B – An increase in elevation of nearly 2 feet was observed in the data (Figure 8). There was one point showing a sudden increase of elevation of over 7 feet that was considered to be an anomaly. A gradual decrease in groundwater elevation also coincides with the termination of the injection test. The data suggests that amendment point AW0077B, 85 feet to the north, influenced the groundwater elevation in this observation well. Amendment point AW0033C is 275 feet away, and screened in a different sand zone.
- TMW08 – A gradual increase of 0.5 inches was observed (Figure 9). The amendment points were 170 (AW0077B) and 200 feet (AW0033C) away. This data suggests that the amendment points have minimal influence on groundwater elevation at these distances.

Based on the groundwater elevation data collected from the monitoring wells, groundwater influence can be measured at distances up to 90 feet from the injection wells.

Groundwater Sample Results

Groundwater samples were collected from AW0082 and AW0103 on January 14, 2005 and submitted to Severn Trent Laboratories, Inc. The samples were analyzed for TOC, volatile organic compounds (VOCs), and total alkalinity. The groundwater samples were collected with disposable bailers due to well access limitations because of rainstorms—no field parameters were collected. Minimal TOC concentrations were detected in the two monitoring wells. Because the well installation on Lot 8 is currently in progress, the only two available wells for monitoring were over 100 feet from the injection points and significant influence was not expected. The following table summarizes the lab results.

Laboratory Data:

Well	Total Organic Carbon	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	TCE	Bicarbonate Alkalinity
	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)
AW0082	2.3	140	4.7	2.6	42	219
AW0103	2.6	68	2.9	<1.0	26	172

Notes: DCE = dichloroethene; TCE = trichloroethene; mg/L = micrograms per liter; µg/L = micrograms per liter

Conclusions

Data collected during the amendment injection test on amendment points in Lot 8, suggested that fermentation of the carbohydrate solution is generating gas and increasing pressure in the amendment points during injection. A buffer solution of sodium bicarbonate was used during injection events at the Building 2 site, so an alternate buffer solution, sodium phosphate, was tested in the Lot 8 wells. Additionally, an un-buffered control solution was tested. The data does not reflect significant differences in the "injectability" of buffered versus non-buffered amendment solutions. Gas generation and pressure build-up in the amendment points was not dependant on the buffering agent (or lack of buffer). Because pressure build-up one week following the test was greater in the amendment points installed in the C-sand, this would indicate that the C-sand is a tighter geologic formation and is slower in dispersing the generated gas.

Since pressure build-up was observed in both buffered and un-buffered amendment solutions, ARCADIS recommends selecting an amendment solution containing a lower concentration of total organic carbon that does not ferment as rapidly as molasses. Sodium lactate has a similar half-life as molasses and creates fewer fermentation products, and may be a suitable donor for the site. Unless the aquifer has a low buffering capacity, ARCADIS recommends that buffers only be added if the groundwater monitoring data indicates a decreasing pH level below 5.

There were no seepages during the test injections, therefore it can be concluded that a maximum injection pressure of 25 psi is adequate for this site. Injection flow rates will be variable depending on the lithology of the screened interval. The slower injection flow rate into AW0077B observed after approximately 900 gallons of injection illustrates the variability of injection flow rates during injection of an amendment solution. This trend was not observed in all amendment points, and should be monitored during future injection events.

The only unforeseen issue observed during the injection test was the slow injection flow rate into two of the amendment points. The excess carbohydrate solution was diverted to the amendment points that exhibited higher flow rates, but only to complete the injection within the one-day time frame.

Tables

ARCADIS

TABLE 1 - ALTERNATE AMENDMENT INJECTION TEST DATA

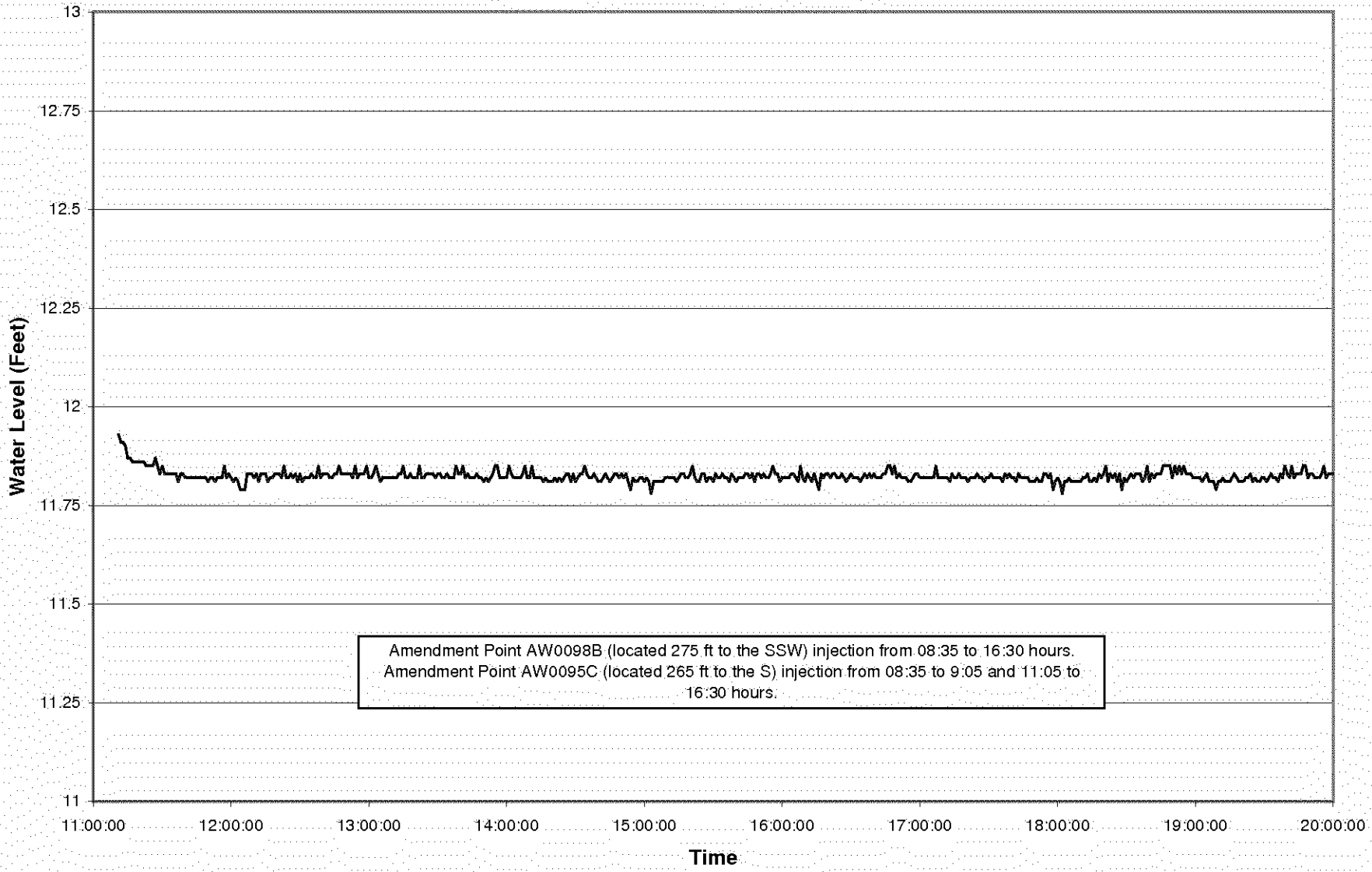
Boeing - Lot 8 Area
19400 Harborgate Way
Torrance, CA 90501
ARCADIS Job Number: CA000594.0005.00006

Well #	Date	Time	Totalizer Reading (gallons)	Injection Pressure (psig)	Injection Flow Rate (gpm)	Injection Solution	Comments
AW0098B	11/8/04	8:35	0			Molasses	
		9:05	171	16	4.4	(No Buffer)	
		9:35	297	17	3.7		
		10:30	474	18	2.9		Flow gradually slowed down.
		11:30	629	18	2.5		
		12:00	740	20	3.2		
		12:30	854	22	3.9		
		13:00	983	25	4.0		
		13:35	1,133	25	4.0		
		13:52	1,200				Stopped injection. Well siphoned to 29" Hg after shutdown.
		14:37	1,200				Restarted injection.
		15:00	1,342	25	5.0		
		15:30	1,437	25	4.0		
		16:00	1,527	25	<1.0		
		16:30	1,564				Well siphoned to 28"Hg after shutdown.
AW0095C	11/8/04	8:35	0			Molasses	
		9:05	59	17	2.0	(No Buffer)	
		9:35	124	17	2.0		
		11:05					Stopped injection (from 9:05 to 11:05).
		11:30	187	18	0.9		Restarted injection.
		12:00	232	20	1.3		
		12:30	281	23	1.7		
		13:00	342	25	2.1		
		13:35	412	25	2.1		
		15:00	597	25	2.3		
		15:30	671	25	2.2		
		16:00	710	25	1.3		
		16:30	747				Well siphoned to 28"Hg after shutdown.
AW0077B	11/9/04	7:45	0			Molasses	
		8:15	68	20	1.2	(Sodium Phosphate Buffer)	
		9:10	90	20	0.2		
		9:15	96	22	0.6		
		9:45	109	25	0.6		
		10:15	119	25	0.4		
		10:45	159	23	1.3		
		10:55					Stopped injection. Well siphoned to 8"Hg after shutdown.
		12:00	299	25	2.6		
		13:00	487	25	3.5		
		14:00	728	25	4.5		
		15:00	983	25	4.8		
		15:15	1,038	26	<1.0		Flowrate quickly diminished.
		15:38	1,068	27	0.5		
AW0033C	11/9/04	7:45	0			Molasses	
		8:15	387	12	16.0	(Sodium Phosphate Buffer)	
		8:45	892	12	16.5		
		9:07	1,201				Stopped injection. Well siphoned to 26"Hg after shutdown.
		15:30		12	16.0		
		15:38	1,328	12	16.0		

Figures

Figure 1 - BOEING C-6

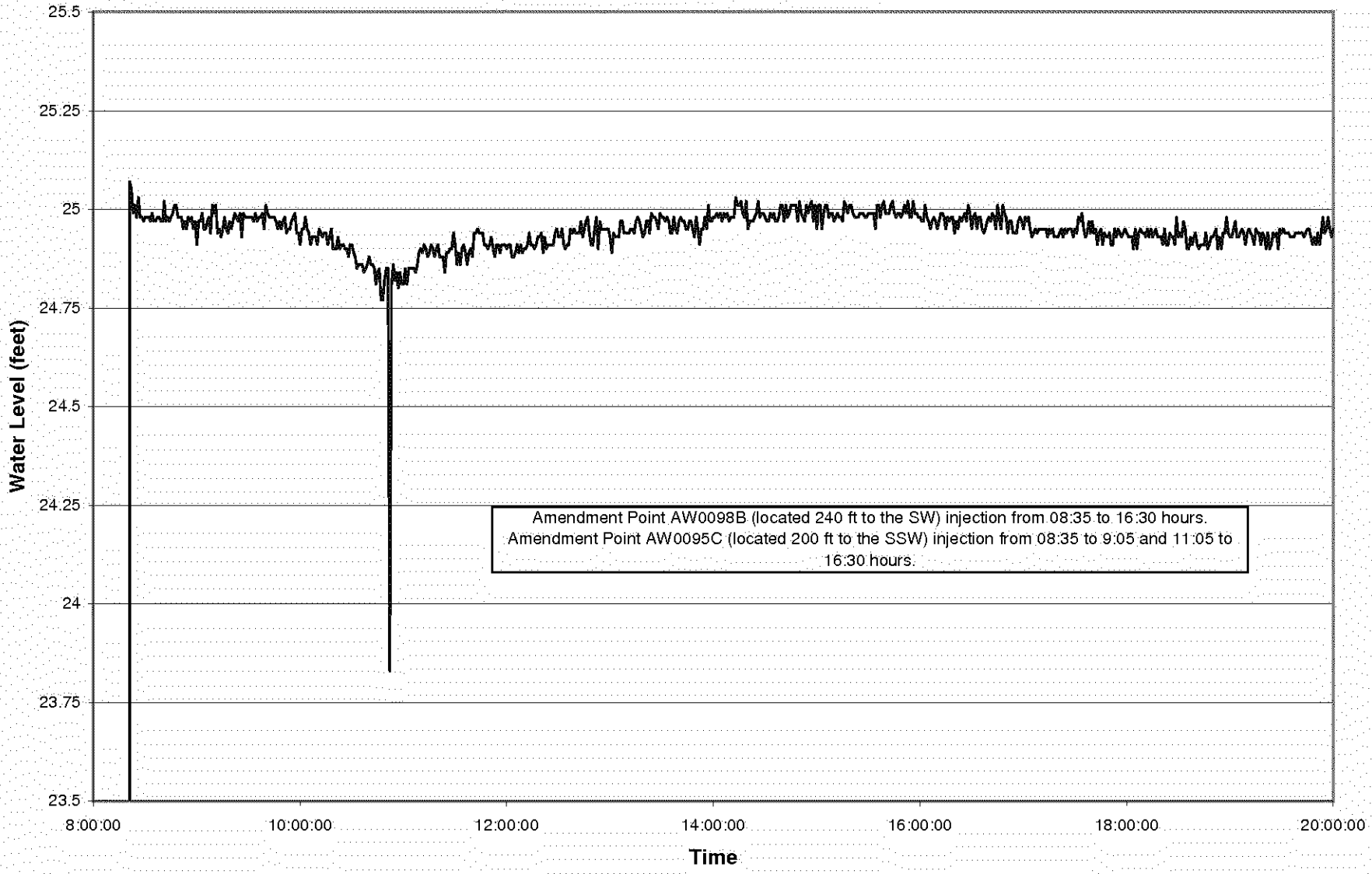
Lot 8 Pre-Injection Test
Tranducer Data - Well AW0033C
November 8, 2004



ARCADIS

Figure 2 - BOEING C-6

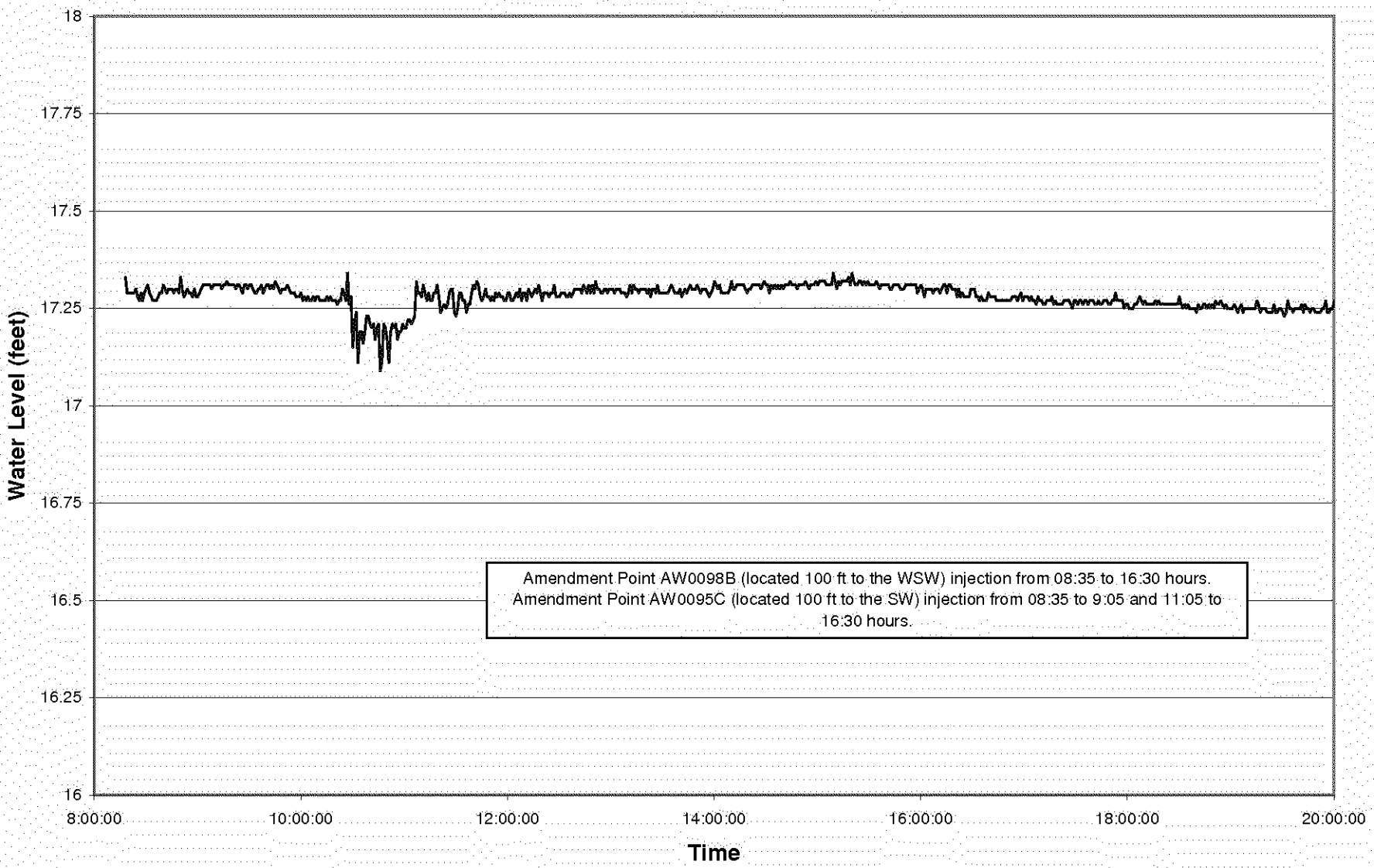
Lot 8 Pre-Injection Test
Transducer Data - Well AW0050C
November 8, 2004



ARCADIS

Figure 3 - BOEING C-6

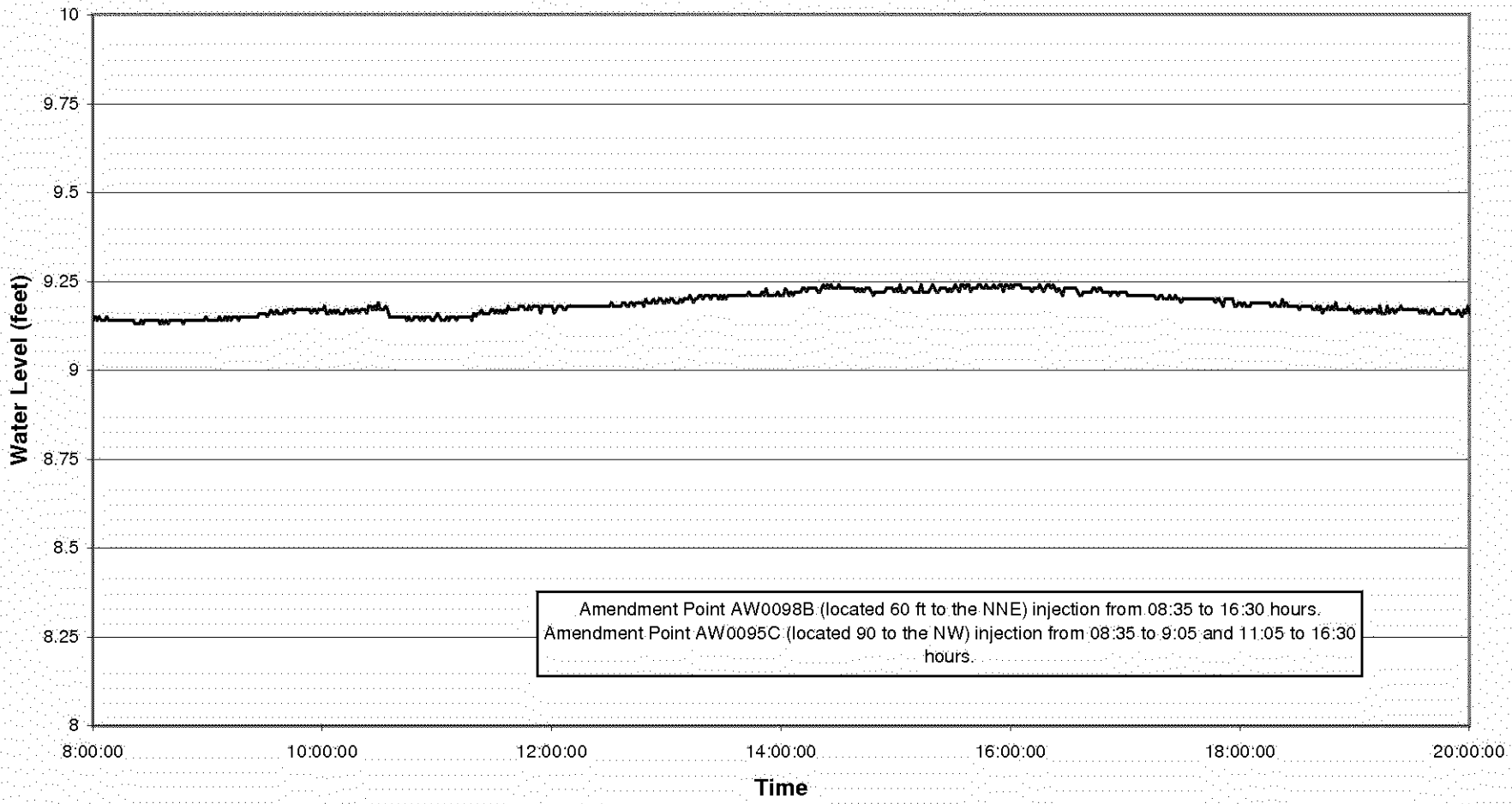
Lot 8 Pre-Injection Test
Transducer Data - Well AW0082C
November 8, 2004



ARCADIS

Figure 4 - BOEING C-6

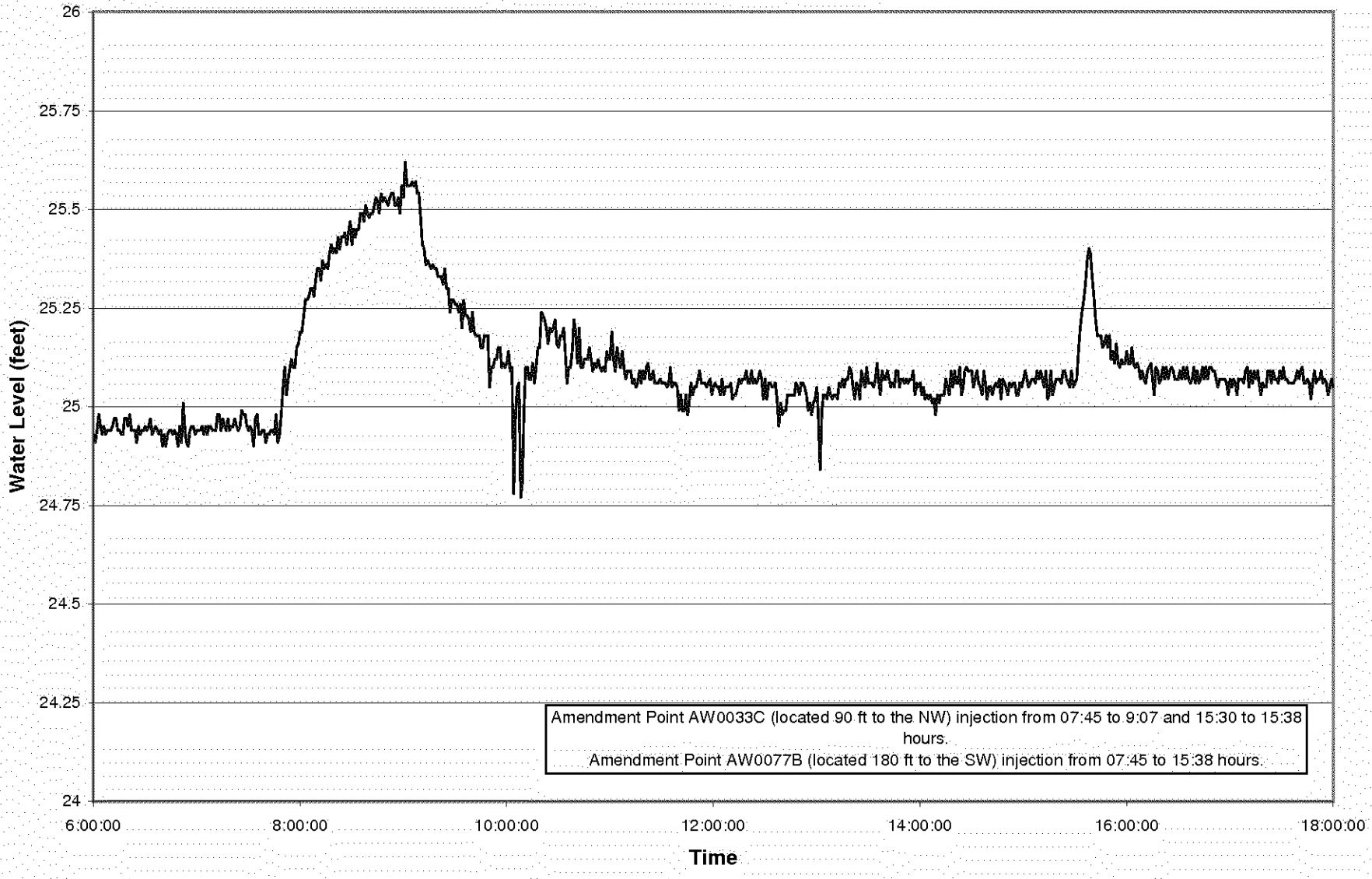
Lot 8 Pre-Injection Test
Transducer Data - Well TMW08
November 8, 2004



ARCADIS

Figure 5 - BOEING C-6

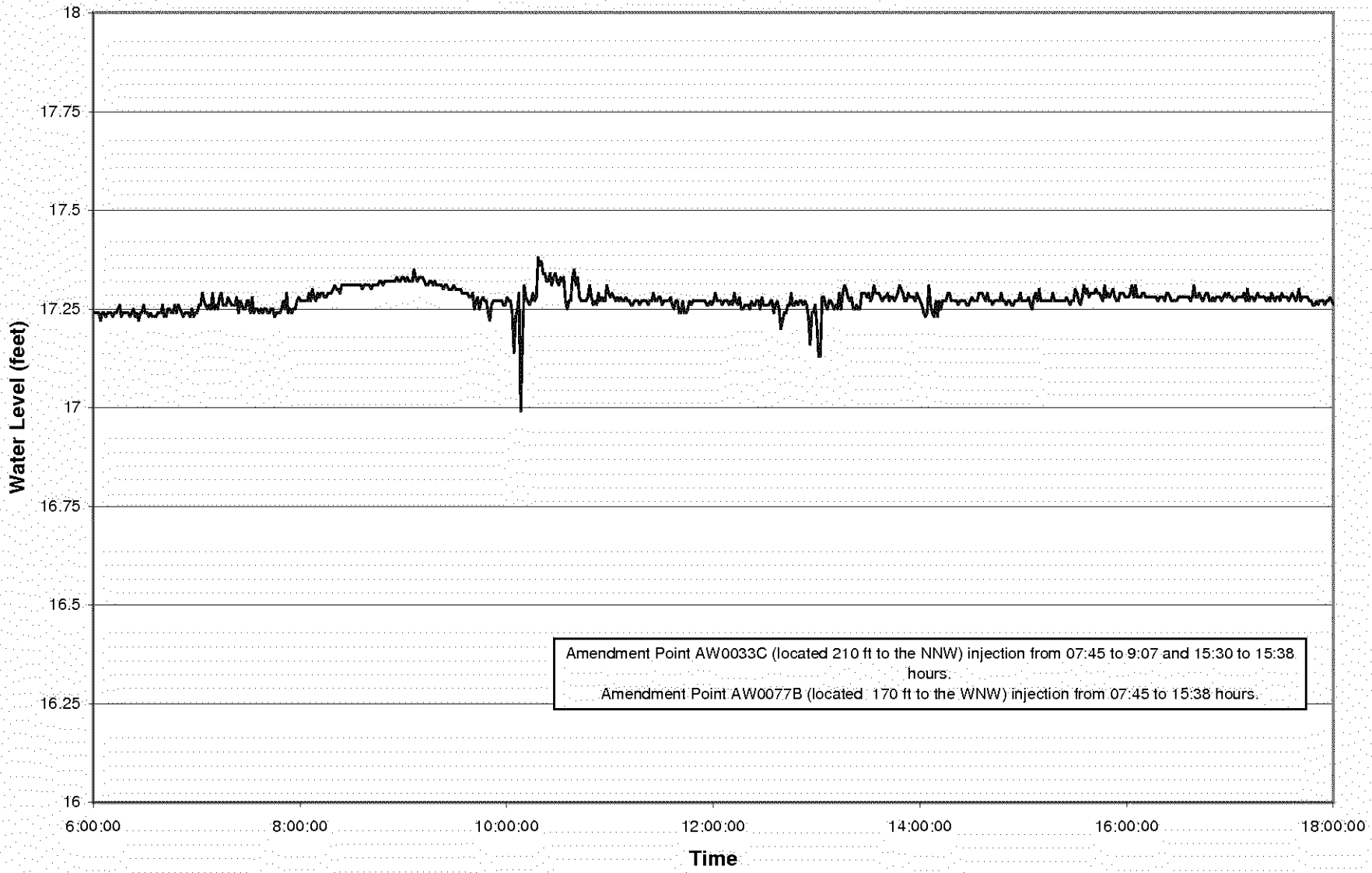
Lot 8 Pre-Injection Test
Transducer Data - Well AW0050C
November 9, 2004



ARCADIS

Figure 6 - BOEING C-6

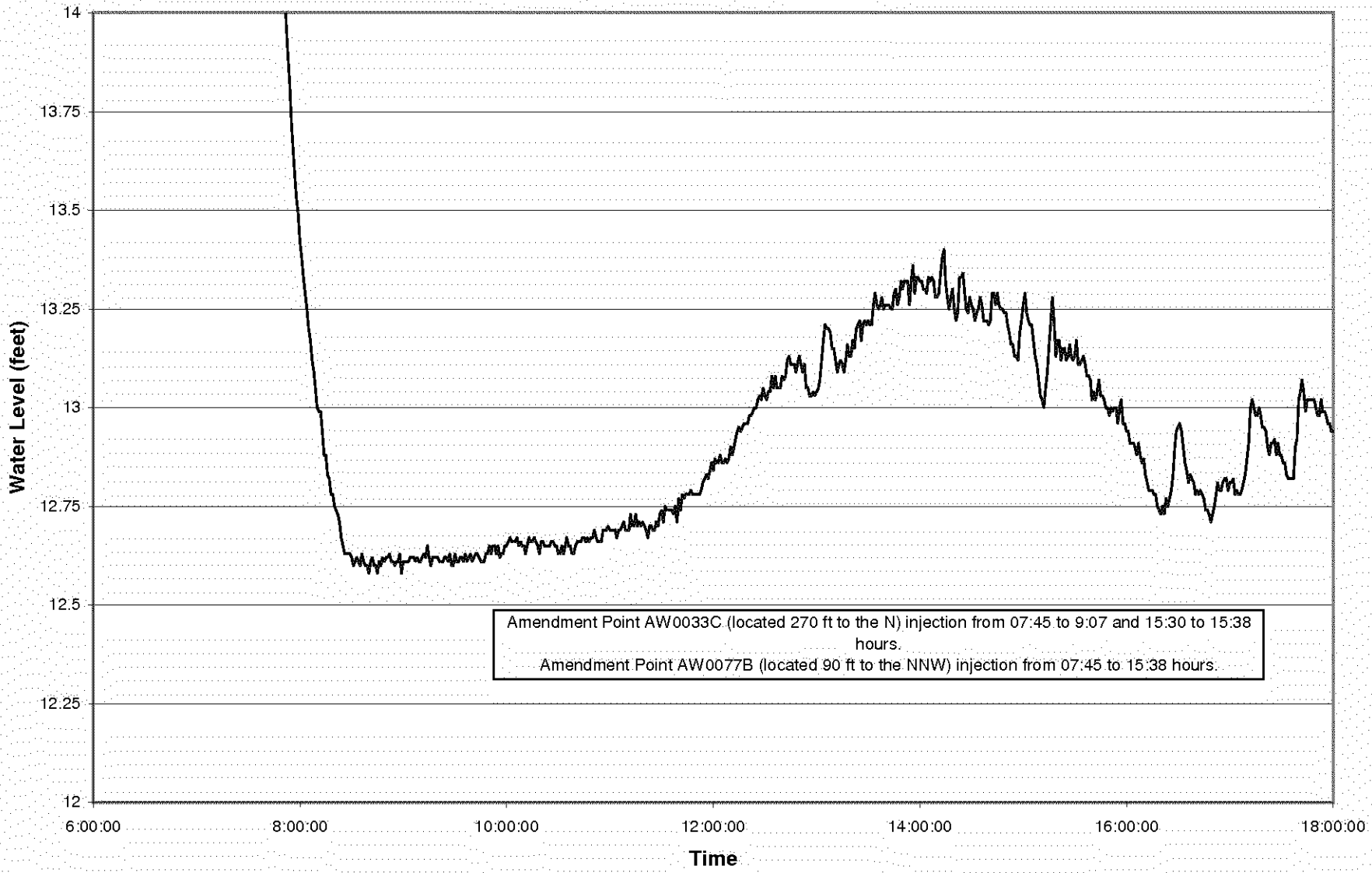
Lot 8 Pre-injection Test
Transducer Data - Well AW0082C
November 9, 2004



ARCADIS

Figure 7 - BOEING C-6

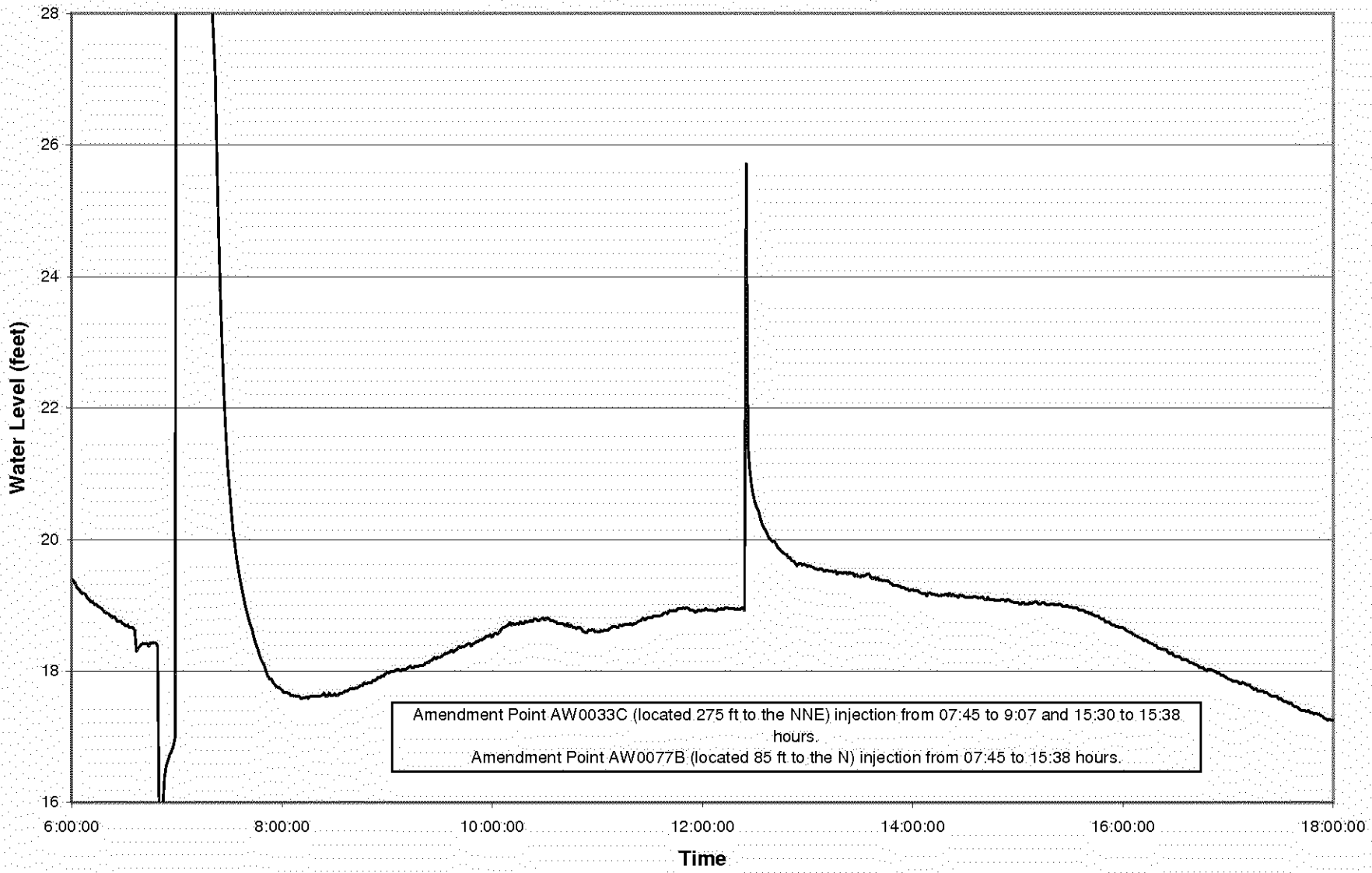
Lot 8 Pre-injection Test
Transducer Data - Well AW0095C
November 9, 2005



ARCADIS

Figure 8 - BOEING C-6

Lot 8 Pre-Injection Test
Transducer Data - Well AW0098B
November 9, 2004



ARCADIS

Figure 9 - BOEING C-6

Lot 8 Pre-Injection Test
Transducer Data - Well TMW08
November 9, 2004